NATIONAL AERONAUTICS AND SPACE ADMINISTRATION

*Space Programs Summary 37-46, Vol. VI*

# *Space Exploration Programs and Space Sciences*

**For the Period May 1 to June 30, 1967**




**JET PROPULSION LABORATORY**
**CALIFORNIA INSTITUTE OF TECHNOLOGY**
**PASADENA, CALIFORNIA**

July 31, 1967

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## Preface

The Space Programs Summary is a six-volume bimonthly publication designed to report on JPL space exploration programs and related supporting research and advanced development projects. The titles of all volumes of the Space Programs Summary are:

Vol. I. *The Lunar Program* (Confidential)

Vol. II. *The Planetary–Interplanetary Program* (Confidential)

Vol. III. *The Deep Space Network* (Unclassified)

Vol. IV. *Supporting Research and Advanced Development* (Unclassified)

Vol. V. *Supporting Research and Advanced Development* (Confidential)

Vol. VI. *Space Exploration Programs and Space Sciences* (Unclassified)

The Space Programs Summary, Vol. VI, consists of: an unclassified digest of appropriate material from Vols. I, II, and III; an original presentation of the JPL quality assurance and reliability efforts, and the environmental- and dynamic-testing facility-development activities; and a reprint of the space science instrumentation studies of Vols. I and II. This instrumentation work is conducted by the JPL Space Sciences Division and also by individuals of various colleges, universities, and other organizations. All such projects are supported by the Laboratory and are concerned with the development of instruments for use in the NASA space flight programs.

Approved by:

W. H. Pickering

W. H. Pickering, Director

*Jet Propulsion Laboratory*

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# I. *Surveyor* Project

**THE LUNAR PROGRAM**

## A. Introduction

The *Surveyor* flight spacecraft are designed to span the gap between the *Ranger* Project and the *Apollo* Project by making soft landings on the moon to extend our knowledge of lunar conditions and determine the suitability of sites for proposed *Apollo* spacecraft landings.

Hughes Aircraft Company (HAC), Space Systems Division, is under contract to fabricate the *Surveyor* A-21 spacecraft. The launch vehicle, a combination *Atlas/Centaur*, is provided by General Dynamics/Convair. Control, command, and tracking functions for the *Surveyor* missions are performed by the *Surveyor* Mission Operations System and the JPL Deep Space Network.

*Surveyor I*, the first flight spacecraft, was launched from Cape Kennedy, Florida, on May 30, 1966, and soft-landed on the moon on June 2, 1966. By June 14, when lunar sunset occurred, approximately 100,000 commands had been received by the spacecraft, and 10,338 pictures of the spacecraft and its immediate vicinity had been transmitted. During the second lunar day, 812 additional pictures were transmitted by *Surveyor I*.

*Surveyor II*, the second flight spacecraft, was launched from Cape Kennedy on September 20, 1966. The spacecraft performed nominally until the command was given for midcourse thrust execution. At that time, one vernier engine did not ignite. The resulting imbalance of thrust from the other two vernier engines imposed a tumbling motion on the spacecraft, from which it failed to recover. The *Surveyor II* mission was terminated on September 22 after all contact with the spacecraft had been lost.

*Surveyor III*, the third flight spacecraft, was launched from Cape Kennedy on April 17, 1967, and soft-landed on the moon, in a crater of the Ocean of Storms, on April 19, 1967. By the end of the first lunar day, the spacecraft had responded to more than 30,000 commands and had transmitted 6315 pictures of the spacecraft and its immediate vicinity. The first photographs were taken of an eclipse of the sun by the earth. Successful surface sampler experiments were conducted; four trenches were dug in the lunar soil, the largest of which was 2 in. wide, 10 in. long, and 7½ in. deep. After the dawn of the second lunar day, eight separate attempts to revive the spacecraft were unsuccessful, and the *Surveyor III* mission was terminated.

The fourth flight spacecraft is at the Eastern Test Range, and preflight preparations are proceeding on schedule.

## B. *Surveyor III* Mission

### 1. Spacecraft Launch and Operations

The highly successful flight of the *Surveyor III* spacecraft, starting from launch pad 36B at Cape Kennedy and culminating in a soft lunar landing in a crater within the Ocean of Storms, was accomplished between April 17, 1967 (GMT day 107), and April 20 (GMT day 110). Following a smooth countdown (except for a 51-min hold at $T - 5$ to analyze the results of special SC-5 and -3 on-stand roll tests) *Surveyor III* was launched at 07:05:01 GMT (23:05:01 PDT) and proceeded smoothly through a $64^h59^m17^s$ flight, with touchdown occurring at 00:04:18 GMT on day 110 (Fig. 1). Because of the loss of the 14-ft mark during terminal descent and the failure of the vernier engines to shut off automatically, the spacecraft hopped twice after initial touchdown. However, the landing of the *Surveyor III* spacecraft was softer than that of *Surveyor I*. Estimated touchdown velocity was 7 ft/s. Table 1 gives the time at which major milestones of the mission occurred up to the receipt of the first 600-line TV picture.

The only confirmed spacecraft malfunction that occurred during the flight was the nonreceipt of the 14-ft mark during terminal descent. A lower than expected surface sampler auxiliary electronics temperature was anomalous.

Suspected unequal thrust indications of the vernier engines obtained during midcourse correction were judged, after considerable analysis, to be most likely within the error resolution of the *Surveyor* signal processing system.

During the postlanding period, approximately at the time of the second touchdown, the telemetry data became garbled. A command was transmitted, the engines shut off, and the spacecraft dropped to the lunar surface. Over a period of time, the spacecraft performance analysis and command group was able to generate correction factors for the telemetry signals and obtain realistic

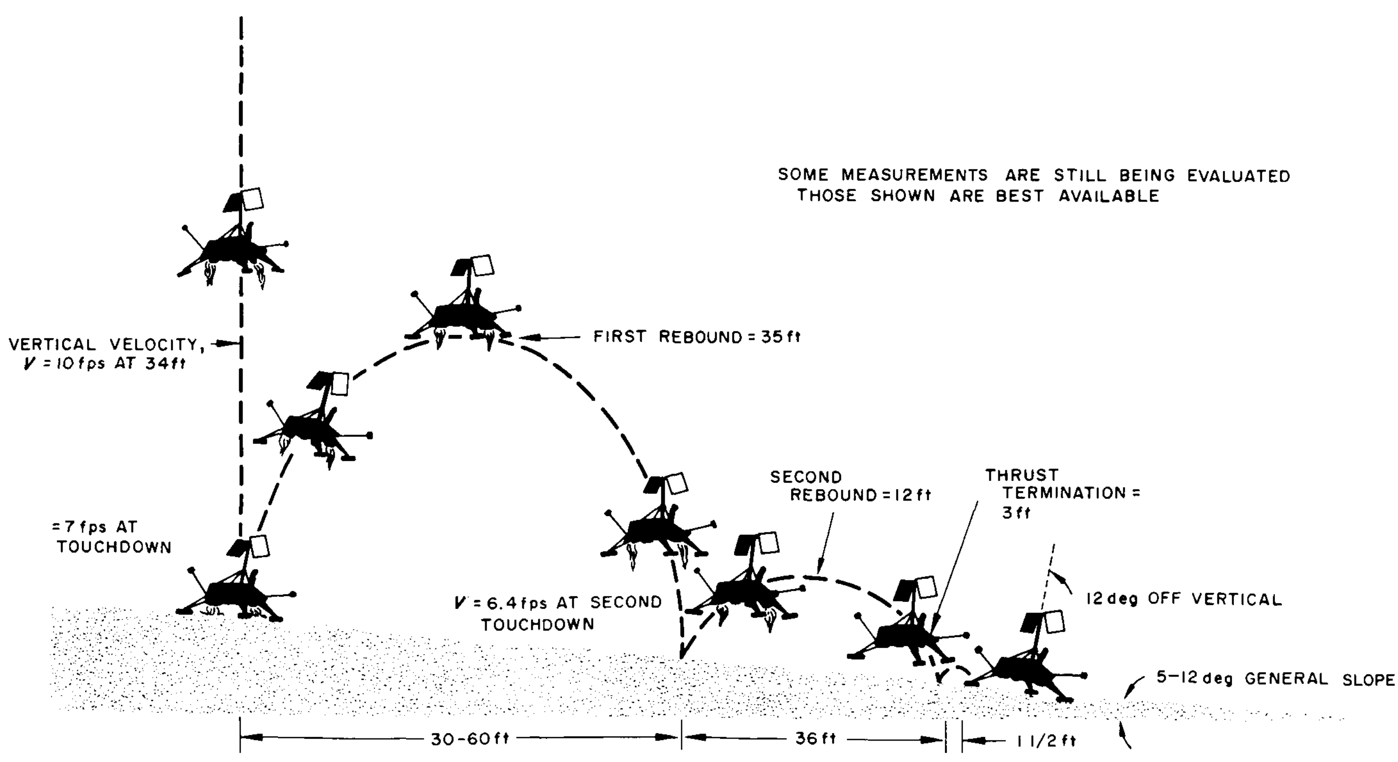


**Fig. 1. *Surveyor III* spacecraft landing profile**

**Table 1. *Surveyor III* mission milestones**

| Event | April 1967, day | Time of event (PDT), h, min, s | Time after launch |
|---|---|---|---|
| Launch | 16 | 23:05:01 | |
| Injection | | 23:38:49 | $33^m48^s$ |
| Separation | | 23:39:54 | $34^m33^s$ |
| Automatic sun acquisition completed | | 23:47:58 | $42^m57^s$ |
| Automatic solar panel deployment completed | | 23:49:54 | $44^m53^s$ |
| Spacecraft visibility at Canberra began | | 23:54 | $49^m$ |
| Initial DSIF acquisition (two-way lock) confirmed | 17 | 00:00 | $55^m$ |
| First ground command sequence initiated | | 00:09:48 | $1^h4^m47^s$ |
| Canopus verification started | | 08:09:12 | $9^h9^m11^s$ |
| Canopus acquisition completed | | 08:27:51 | $9^h22^m50^s$ |
| First premidcourse attitude maneuver initiated | | 20:46:50 | $21^h41^m49^s$ |
| Midcourse thrust executed | | 21:00:02 | $21^h55^m01^s$ |
| Sun reacquired | | 21:04:37 | $21^h59^m36^s$ |
| Canopus reacquired | | 21:08:11 | $22^h3^m10^s$ |
| First terminal descent attitude maneuver initiated | 19 | 15:23:30 | $64^h18^m29^s$ |
| Retromotor thrust direction properly positioned | | 15:32:50 | $64^h27^m49^s$ |
| Final roll completed | | 15:36:42 | $64^h31^m42^s$ |
| Altitude marking radar mark generated | | 16:01:13 | $64^h56^m12^s$ |
| Vernier engine ignition | | 16:01:18 | $64^h56^m17^s$ |
| Retroengine ignition | | 16:01:19 | $64^h56^m18^s$ |
| Retroengine separation | | 16:02:14 | $64^h57^m13^s$ |
| Radar control initiated | | 16:02:15 | $64^h57^m14^s$ |
| Touchdown (initial) | | 16:04:18 | $64^h59^m17^s$ |
| Touchdown (second) | | 16:04:42 | $64^h59^m41^s$ |
| Touchdown (final) | | 16:04:54 | $64^h59^m53^s$ |
| First 200-line TV picture | | 17:02:32 | $65^h57^m31^s$ |
| Earth/sun acquisition completed | 20 | 00:15:00 | $73^h9^m59^s$ |
| First 600-line TV picture | | 00:42:00 | $73^h36^m59^s$ |

telemetry indications to accurately assess spacecraft performance and accomplish power and thermal management. Good 200- and 600-line TV pictures were obtained whenever the TV system was operated, and the surface sampler performed all tasks to specification.

### 2. Operational Capabilities

Unique operational capabilities were demonstrated during the *Surveyor III* mission:

(1) Steady, consistent, and methodical sending of command sequence after command sequence (21 in the first 55 min) after touchdown, upon receipt of essentially unintelligible telemetry data, in order to correct the apparent anomaly and to protect the spacecraft. This was made possible by real-time operational personnel experience and the highly flexible and efficient *Surveyor* command link designed for such a situation, using man in a decision loop to control and evaluate spacecraft performance. The command rate for these nonstandard extemporaneous sequences was more than 1½ per min, which exceeded the rate during active periods, such as the midcourse correction and terminal descent.

(2) Remarkable positioning of the solar panel essentially on the sun, and the planar array rather precisely on the earth, in only 100 min, without the possibility of reference to *Surveyor* telemetry signals (or any other *Surveyor* output for 50 min until earth acquisition) and with the spacecraft in a lunar crater on an unknown slope of some 12.5 deg.

(3) Ability of the spacecraft performance analysis and command trend and failure analysis group to come up with calibration fixes to practically all telemetry signals, for all commutators, at 17.2 bits/s some 144 h after touchdown, allowing accurate assessment of spacecraft performance throughout *Surveyor III's* first lunar day operations.

(4) Ability of the spacecraft performance analysis and command real-time performance analysis group to come up with thermal channel correction factors based on *Surveyor I* experience some 48 to 130 h after touchdown, which provided the first thermal data interpretation breakthrough of the first lunar day operations. The first proof of the assumed correction factors was obtained some 96 h after touchdown, when transmitter frequency was utilized to verify compartment temperature.

(5) Presence and performance of the new spacecraft performance analysis and command trend and failure analysis group. Studies were accomplished which provided a firmer base on which to justify real-time decisions and could have been the basis for reversing or changing real-time decisions, if necessary. In particular, the prelaunch analysis of the roll actuator anomaly, the midcourse anomaly relative to uneven engine thrust levels, and the posttouchdown analysis that resulted in updated calibration coefficients were detailed studies that the real-time performance analysis group could not have found time to accomplish. The last-named analysis was one of the major contributions to accurate performance assessment of the spacecraft after touchdown.

## C. Systems Engineering and Testing

### 1. SC-5 (Fifth Flight Spacecraft)

After SC-5 solar-thermal-vacuum testing, it was necessary to replace the test thermal blankets in the compartments with flight-type blankets. Vernier-engine vibration was successfully completed, and the spacecraft was shipped to General Dynamics/Convair for the combined systems test.

### 2. SC-6 and -7 (Sixth and Seventh Flight Spacecraft)

The SC-6 spacecraft completed initial system sine checkout, and preparations for mission-sequence/electromagnetic-interference and solar-thermal-vacuum testing are under way. Modifications for installation of the surface sampler on the SC-7 spacecraft were completed, and initial system checkout was resumed.

### 3. S-9 Test Model

The S-9 test model was modified structurally to represent an SC-5-type spacecraft. The present S-9 vehicle configuration includes a JPL-furnished solar panel; a flight-type alpha-scattering mechanism with a dynamically simulated sensor head; SC-5-type thermal compartments A, B, and C; auxiliary TV viewing mirrors; and an SC-5-type vernier-engine 1 bracket.

The S-9 test model was instrumented with strain gages and accelerometers and vibration tests were conducted. Drop testing of the vehicle is scheduled to start on July 11, 1967.

# II. *Mariner* Venus 67 Project

## THE PLANETARY–INTERPLANETARY PROGRAM

### A. Introduction

The primary objective of the *Mariner* Venus 67 Project is to conduct a flyby mission to Venus in 1967 to obtain scientific information which will complement and extend the results obtained by *Mariner II* relevant to determining the origin and nature of Venus and its environment. Secondary objectives are to: (1) acquire engineering experience in the conversion of a spacecraft designed for a mission to Mars (spare flight spacecraft from *Mariner* Mars 1964 Project) into one designed for a mission to Venus and in the operation of such a spacecraft, and (2) obtain information on the interplanetary environment during a period of increasing solar activity. There are seven scientific experiments on board the spacecraft. The Principal Scientific Investigators for these experiments are given in Table 1.

On June 14, 1967, the *Mariner V* spacecraft was launched from Cape Kennedy, Florida. In the magnetosphere, science instruments made solar-plasma, radiation, and magnetic-field measurements, and hydrogen in the earth's geocorona was observed. The spacecraft acquired the star Canopus. After a successful midcourse correction maneuver was performed, ranging instrumentation was turned on, and ranging data were obtained. Spacecraft systems are operating normally.

**Table 1. *Mariner* Venus 67 Principal Scientific Investigators**

| Experiment | Principal Scientific Investigator | Affiliation |
|---|---|---|
| S-band radio occultation | A. J. Kliore | Jet Propulsion Laboratory |
| Ultraviolet photometer | C. A. Barth | University of Colorado |
| Dual-frequency radio propagation | V. R. Eshleman | Stanford University |
| Helium magnetometer | E. J. Smith | Jet Propulsion Laboratory |
| Solar plasma probe | H. S. Bridge | Massachusetts Institute of Technology |
| Trapped radiation detector | J. A. Van Allen | State University of Iowa |
| Celestial mechanics | J. D. Anderson | Jet Propulsion Laboratory |

The M67-1 flight-support spacecraft was returned to JPL from the Eastern Test Range and is now in operation in the Spacecraft Assembly Facility area. The M67-1 spacecraft will be used to determine the cause of *Mariner V* anomalies that may be encountered during flight and to support tests of command operations.

## B. *Mariner V* Launch and Operations

The *Mariner V* spacecraft was launched from Cape Kennedy, Florida, on June 14, 1967.

During the normal roll-search mode of the spacecraft, the Canopus sensor locked on the far limb of the earth. Two roll override commands were then sent to the spacecraft. These commands stepped the spacecraft from the far limb to the near limb of earth and then to the star Canopus.

Prior to the acquisition of Canopus, the science instruments made measurements of the environment in three distinct regions:

(1) Inside the magnetosphere, the trapped radiation detector monitored the Van Allen radiation belts, the helium magnetometer measured the geomagnetic field, and the plasma probe detected no plasma.

(2) Passage through the magnetopause (outer boundary of the magnetosphere) was marked by the first detection of plasma.

(3) Passage through the plasma shock wave was indicated by a sudden decrease in the magnetic field, and a change in the energy spectrum of the solar plasma to one typical of the interplanetary wind. Disturbances observed in the magnetic field indicated some solar activity. The geiger counter pointed toward the sun detected at least one burst of solar X-rays.

Throughout the period when the spacecraft was rolling, the ultraviolet photometer periodically observed the hydrogen in the earth's geocorona.

The *Mariner V* spacecraft successfully performed a midcourse correction maneuver on June 19. Motor burn during the midcourse correction lasted for 17.66 s. The spacecraft will now pass on the antisolar side of Venus at a distance of 2460 mi from the surface of the planet. The flyby geometry is considered to be well within the tolerance required to meet the mission objectives.

Following the midcourse correction maneuver, ranging instrumentation was turned on for the first time with a *Mariner*-type spacecraft. Ranging data were obtained by the MK-I (lunar) equipment at the Pioneer and Robledo DSSs. The MK-II (planetary) ranging equipment at the Mars DSS also acquired data during a portion of one pass. The ranging data thus far obtained on the *Mariner V* mission exceeds that required to determine the trajectory and flyby conditions of the spacecraft. These data are being retained for post-mission analysis to determine the subtle effects that are not measurable with present analytic tools.

## C. Systems Test Complex

The systems-test-complex data computer system was assembled and checked out at the Eastern Test Range, and subsequently was connected to the associated data input subsystem located on the systems test complex to enable support of the M67-1 system verification test on May 1, 1967. After this test, system tests were performed on the M67-2 flight spacecraft (*Mariner V*). The Cape Kennedy DSS/spacecraft interface test was conducted. Then the systems test complex supported *Mariner V* launch countdowns and approximately 12 min of launch phase operation while telemetry data was being received over the *Agena* link or from Antigua.

The systems-test-complex data computer system was disassembled on June 20 and returned to JPL. The system was installed in the Spacecraft Assembly Facility, where it will be available for M67-1 spacecraft test support, and will be used for *Mariner* Mars 1969 program development.

# I. *Surveyor* Project

## THE LUNAR PROGRAM

### A. Introduction

The *Surveyor* flight spacecraft are designed to span the gap between the *Ranger* Project and the *Apollo* Project by making soft landings on the moon to extend our knowledge of lunar conditions and determine the suitability of sites for proposed *Apollo* spacecraft landings.

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*Surveyor III*, the third flight spacecraft, was launched from Cape Kennedy on April 17, 1967, and soft-landed on the moon, in a crater of the Ocean of Storms, on April 19, 1967. By the end of the first lunar day, the spacecraft had responded to more than 30,000 commands and had transmitted 6315 pictures of the spacecraft and its immediate vicinity. The first photographs were taken of an eclipse of the sun by the earth. Successful surface sampler experiments were conducted; four trenches were dug in the lunar soil, the largest of which was 2 in. wide, 10 in. long, and 7½ in. deep. After the dawn of the second lunar day, eight separate attempts to revive the spacecraft were unsuccessful, and the *Surveyor III* mission was terminated.

## Erratum

In Space Programs Summary 37-45, Vol. VI, p. 9, paragraph 1d should have been as follows:

*d. Science instruments.* The trapped radiation detector was mounted at the same location as that of the *Mariner* Mars 1964, with the instrument reversed to provide proper sun-line orientation. The magnetometer experiment remained in the *Mariner* Mars 1964 location on the low-gain antenna, but some thermal control effort was required to ensure acceptable temperatures. The plasma probe was moved from the solar panel and placed on an auxiliary support structure inboard of the lower ring on the sun side of the spacecraft. The ultraviolet photometer was located over Bay II at a cone angle of 90 deg, to allow a field of view compatible with the planet encounter geometry. The dual-frequency radio receiver, the new experiment that was added to the science payload, was packaged as an electronics subassembly and placed in the Bay III electronics assembly.

# III. *Mariner* Mars 1969 Project

## THE PLANETARY–INTERPLANETARY PROGRAM

### A. Introduction

The primary objective of the *Mariner* Mars 1969 Project is to conduct two flyby missions to Mars in 1969 to make exploratory investigations of the planet which will set the basis for future experiments—particularly those relevant to the search for extraterrestrial life. The secondary objective is to develop the technology needed for succeeding Mars missions.

The spacecraft design concept will be based on that of the successful *Mariner IV* spacecraft developed under the *Mariner* Mars 1964 Project. However, considerable modifications will be made to meet the 1969 mission requirements and to enhance mission reliability.

The launch vehicle will be the *Atlas/Centaur SLV-3C*. This vehicle, developed under contract for and direction of the Lewis Research Center by General Dynamics/Convair, has a single- or double-burn capability in its second stage and a considerably increased performance rating over the *Atlas D/Agena D* used in the *Mariner IV* mission.

*Mariner* Mars 1969 missions will be supported by the Eastern Test Range launch facilities at Cape Kennedy, the tracking and data acquisition facilities of the Deep Space Network, and other NASA facilities.

The six planetary-science experiments selected by NASA for the *Mariner* Mars 1969 missions are the following: TV, infrared spectrometer, ultraviolet airglow spectrometer, infrared radiometer, S-band occultation, and celestial mechanics. Additionally, a planetary-approach-guidance engineering experiment will be incorporated to test the feasibility and flight performance of onboard optical sensors and associated data processing techniques necessary for optical approach guidance. The Scientific Investigators for the planetary-science experiments are listed in Table 1.

During this reporting period, minor design changes were made to spacecraft components. Spacecraft subsystem efforts were directed toward manufacturing procurements.

Table 1. *Mariner Mars* 1969 Scientific Investigators

| Experiment | Scientific Investigator | Affiliation |
|---|---|---|
| TV | R. B. Leighton[a] | California Institute of Technology |
| | B. C. Murray | California Institute of Technology |
| | R. P. Sharp | California Institute of Technology |
| | N. H. Horowitz | California Institute of Technology |
| | J. D. Allen | Jet Propulsion Laboratory |
| | A. G. Herriman | Jet Propulsion Laboratory |
| | L. R. Malling | Massachusetts Institute of Technology |
| | R. K. Sloan | Jet Propulsion Laboratory |
| | M. E. Davies | Rand Corporation |
| | C. Leovy | Rand Corporation |
| Infrared spectrometer | G. C. Pimentel[a] | University of California, Berkeley |
| | K. C. Herr | University of California, Berkeley |
| Ultraviolet airglow spectrometer | C. A. Barth[a] | University of Colorado |
| | W. G. Fastie | Johns Hopkins University |
| Infrared radiometer | G. Neugebauer[a] | California Institute of Technology |
| | G. Munch | California Institute of Technology |
| | S. C. Chase | Santa Barbara Research Center |
| S-band occultation | A. J. Kliore[a] | Jet Propulsion Laboratory |
| | D. L. Cain | Jet Propulsion Laboratory |
| | G. S. Levy | Jet Propulsion Laboratory |
| Celestial mechanics | J. D. Anderson[a] | Jet Propulsion Laboratory |

[a]Principal Scientific Investigator.

## B. Design and Development

### 1. Spacecraft Subsystems

To improve specific spacecraft operations and increase capabilities, numerous design changes were made to subsystem components (Table 2). As a result of these and previous design changes, spacecraft weight has increased. A summary of subsystem weights, with total spacecraft weight, in November 1966, March 1967, and June 1967 is presented in Table 3.

### 2. Spacecraft Structures

The *Mariner* Mars 1969 spacecraft structural design is essentially completed. The structures subsystem consists of: (1) the spacecraft adapter, (2) the basic octagonal structure, (3) the solar panels, (4) the high-gain antenna structure, and (5) the low-gain antenna structure.

Table 2. *Mariner Mars* 1969 spacecraft design changes

| Subsystem | Change |
|---|---|
| Structures | Strengthening of solar panel support structure |
| | Additional accelerometer amplifiers |
| Radio frequency | Power consumption increase |
| Flight command | Redundant coded command interfaces |
| Power | 20-mil cover glass incorporation |
| | Addition of fuse box |
| | Incorporation of DC-50, heater power switch |
| | Data storage subsystem power switching change |
| | Voltage fail-sense circuitry change |
| Central computer and sequencer | No significant changes |
| Flight telemetry | Incorporation of independent mode change capability |
| Attitude control | Reduction in pitch and yaw deadband |
| Pyrotechnic | Deletion of ultraviolet spectrometer cover removal function |
| | Change in infrared spectrometer motor start/cooldown mechanization |
| Cabling | No significant changes |
| Propulsion | Rocket engine relocation |
| Temperature control | Deletion of promethium 147 heat sources |
| Mechanical devices | Incorporation of pneumatic latch for scan platform |
| Approach guidance | No significant changes |
| Data storage | Deletion of analog/digital transfer wait-state |
| | Deletion of recording turnoff from lack of data automation subsystem sync |
| Data automation | Addition of backup command to start recorder |
| Scan control | Scan position telemetry |
| Ultraviolet spectrometer | Elimination of ultraviolet spectrometer cover |
| Television | Incorporation of signal to time analog tape recorder |
| | Implementation of TV cover removal, DC-46 |
| | Addition of TV preconditioning command, DC-48 |
| | Incorporation of capability to reset TV aperture |
| Infrared spectrometer | Choice of hydrogen for infrared spectrometer coolant gas |
| Infrared radiometer | Addition of precondition command, DC-48 |

**Table 3. *Mariner* Mars 1969 spacecraft weight summary**

| Subsystem | November 1966 | March 1967 | June 1967 |
|---|---|---|---|
| Structure | 180.1 | 170.4 | 195.9 |
| Radio frequency | 46.7 | 58.2 | 47.9 |
| Flight command | 10.0 | 11.4 | 7.5 |
| Power | 102.5 | 106.5 | 116.0 |
| Central computer and sequencer | 18.0 | 24.0 | 24.0 |
| Flight telemetry | 21.9 | 22.4 | 24.0 |
| Attitude control | 57.3 | 59.6 | 59.6 |
| Pyrotechnic | 12.1 | 12.0 | 10.9 |
| Cabling | 55.8 | 68.7 | 71.2 |
| Propulsion | 45.2 | 46.4 | 46.5 |
| Temperature control | 22.4 | 38.3 | 30.8 |
| Mechanical devices | 42.4 | 43.1 | 44.2 |
| Approach guidance | 6.0 | 10.5 | 10.5 |
| Data storage | 38.0 | 38.0 | 34.2 |
| Data automation | 19.5 | 19.5 | 13.0 |
| Scan control | 12.6 | 18.3 | 18.3 |
| Ultraviolet spectrometer | 30.0 | 30.6 | 30.0 |
| Television | 45.6 | 47.6 | 46.8 |
| Infrared spectrometer | 24.4 | 29.0 | 31.0 |
| Infrared radiometer | 5.0 | 5.0 | 5.6 |
| Total spacecraft design estimate | 795.5 | 859.5 | 867.9 |
| Engineering contingency | 44.1 | 40.0 | 13.6 |
| Total spacecraft weight | 839.6 | 899.5 | 881.5 |

The spacecraft adapter, a 52-in. diameter × 21-in. high cylinder, attaches the spacecraft to the forward structure (*Centaur* adapter) of the *Atlas/Centaur* boost vehicle, and positions the spacecraft base approximately 21 in. above the *Centaur* adapter forward flange.

The octagonal structure, which is approximately 50 in. across the flats and 18 in. high, is the central body of the spacecraft. The structure provides a cavity into which the electronics are mounted and acts as a rigid frame to which the scan platform, solar panels, antennas, and miscellaneous equipment are mounted.

Each of the four solar panels on the spacecraft is approximately 3 × 7 ft and weighs approximately 0.5 lb/ft$^2$. Bonded to the surface of each panel are solar cells and electrical wiring to power the spacecraft. The four panels are mounted to the spacecraft upper ring by hinged joints and are folded up to form a box 3 × 7 ft high. The tips of the panels are latched together through short spring-dashpot struts which quiet the solar panel resonances during boost vibration and permit a lightweight structure to survive the boost environment.

The high-gain antenna structure is composed of a parabolic reflector and a feed support truss. The parabolic reflector, which is 40 in. in diameter, beams the radio waves to earth. This reflector is basically a 0.5-in.-thick honeycomb sandwich parabolic shell utilizing 4-mil aluminum face skins, 2-mil film adhesive bond lines, and 0.7-mil × 0.25-in. cell honeycomb core. The feed support truss locates the antenna feed in the proper position to illuminate the parabolic reflector. This truss is a bonded assembly made of molded 20-mil wall unidirectional fiberglass tubing and machined lexan end fittings.

The low-gain antenna structure has the dual function of being a circular waveguide and the support for the antenna's radiating aperture. The structure is simply a 25-mil wall, 4-in.-diameter aluminum tube 7.7 ft long supported by two spring-dashpot struts and pin-jointed at its base.

### 3. Spacecraft Power

Spacecraft power requirements have increased appreciably. The major increases were:

(1) Radio frequency subsystem: 26.3 W in the high power mode, and 22.3 W in the low power mode.

(2) Temperature control subsystem: 5 or 15 W due to deletion of promethium, and depending upon whether the science platform temperature is at 0 or −10°C.

(3) Scan control subsystem: 18.5 W.

A tradeoff study was performed to try to reduce the power loads of the spacecraft, while at the same time increasing the capability of the solar panels to supply power under worst-case conditions.

The power loads were reduced by: (1) connecting heaters to the reset side of the data storage subsystem power relay, saving approximately 25 W of power during playback; (2) incorporating a direct command to toggle the thermostatic heaters between the battery and the dc bus; and (3) reduction of the platform temperature from 0 to −10°C, which saves 10 W of heater power. Solar panel capability was increased by changing the 6-mil cover glass on the solar panels to 20-mil thickness, thereby gaining from 22 to 26 W under maximum solar flare degradation.

## C. Separation Dynamics Analysis

Analysis was performed regarding the separation of the *Mariner* Mars 1969 spacecraft from the *Centaur* vehicle. The motions, absolute and relative in six degrees of freedom, of the spacecraft and the *Centaur* vehicle were determined during the separation.

The basic mathematical approach to the problem was a straightforward application of the Lagrange equations augmented by undetermined multipliers. The equations of motion were written in a reference frame that has fixed directions in inertial space, but that moves with the pre-separation trajectory of the two bodies, e.g., the spacecraft and the *Centaur* vehicle. The equations of motion were solved on the IBM 7094 computer for the accelerations by Cramer's rule. The accelerations were then twice-integrated to give the velocities and displacements.

The results of the analysis indicate that the *Mariner* Mars 1969 spacecraft will separate from the *Centaur* vehicle with an absolute velocity of 19.5 in./s and a relative velocity of 23.6 in./s. The angular rate produced by the spacecraft CG offset is 0.44 deg/s, corresponding to pitch and yaw rates of 0.30 and 0.67 deg/s, respectively. The maximum *Centaur* residual angular rate is considered to be 1 deg/s. If the direction of this residual angular rate is the same as that caused by the spacecraft CG offset, the combined angular rate will be 1.46 deg/s, corresponding to pitch and yaw rates of 1.01 and 1.06 deg/s, respectively.

## D. Assembly, Handling, and Shipping Equipment

The philosophy for providing *Mariner* Mars 1969 assembly, handling, and shipping equipment is wherever possible to use the equipment utilized in *Mariner* Mars 1964 and *Mariner* Venus 67; to modify and use this equipment if necessary and possible; and, where these approaches are impossible, to procure new equipment.

The spacecraft is mounted on a universal ring from the beginning of octagon structure assembly until mating on the spacecraft adapter prior to encapsulation, except for tests requiring removal from the universal ring. The universal ring mounts on the low-level positioner, which is used to orient the spacecraft as required.

The spacecraft is protected by a metal canister during storage and shipment. The canister bolts to the universal ring. Purge gas will be introduced into the interior of the canister to provide a dry atmosphere during storage and shipment. During idle periods, the spacecraft is stored on a universal ring either on a service dolly or on a transport trailer.

The spacecraft is transported on the universal ring mounted on the transport trailer. For spacecraft movement between installations, the transporter will be shipped in a van (Fig. 1). To permit the spacecraft to fit in the van for shipment, the solar panels are replaced by gas frames, the low-gain antenna is removed, and a shortened protective canister is used.

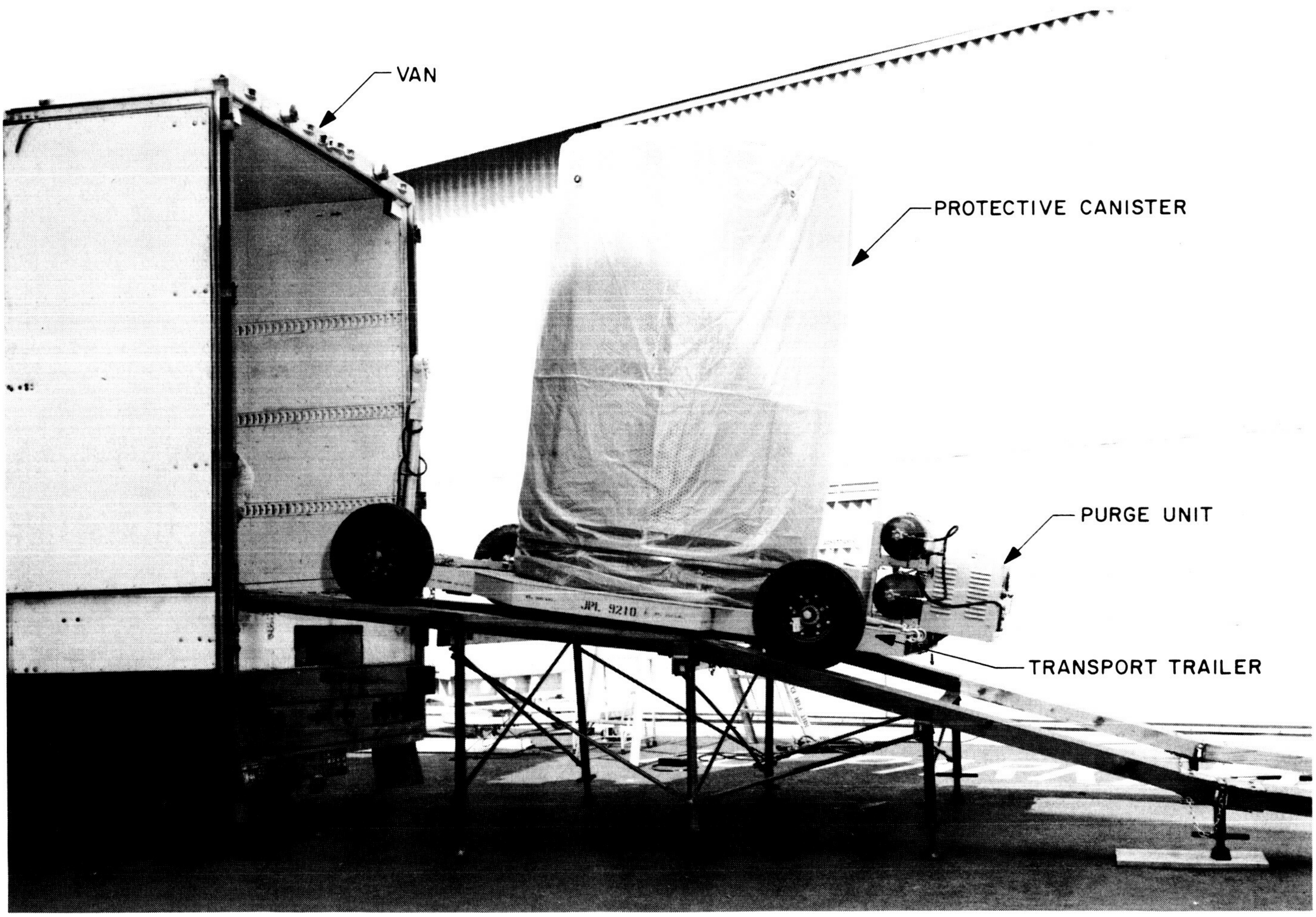


Fig. 1. *Mariner* Mars 1969 transporter and van

# IV. DSN Capabilities and Facilities

## THE DEEP SPACE NETWORK

Established by the NASA Office of Tracking and Data Acquisition and under the system management and technical direction of JPL, the Deep Space Network (DSN) is responsible for two-way communications with unmanned spacecraft traveling from approximately 10,000 mi from the earth to interplanetary distances. [Earth-orbiting scientific and communications satellites and the manned spacecraft of the *Gemini* and *Apollo* Projects are tracked by the Space Tracking and Data Acquisition Network (STADAN) and the Manned Space Flight Network (MSFN), respectively.] NASA space exploration projects supported, or to be supported, by the DSN include the following: (1) *Ranger, Surveyor, Mariner,* and *Voyager* Projects of JPL; (2) *Lunar Orbiter* Project of the Langley Research Center; (3) *Pioneer* Project of the Ames Research Center; and (4) *Apollo* Project of the Manned Spacecraft Center (as backup to MSFN).

Present DSN facilities permit simultaneous control of a newly launched spacecraft and a second spacecraft already in flight. In preparation for increased U.S. activities in space, a capability is being developed for simultaneous control of either two newly launched spacecraft plus two in flight, or four spacecraft in flight. Advanced communications techniques are being implemented to enable obtaining data from, and tracking spacecraft to, planets as far out in space as Jupiter. The main elements of the DSN are described below.

### A. Deep Space Instrumentation Facility

The Deep Space Instrumentation Facility (DSIF) is composed of tracking and data acquisition stations around the world. The deep space stations (DSSs) of the

DSIF and the deep space communication complexes (DSCCs) they comprise are as follows:

| DSS | DSCC |
|---|---|
| Pioneer<br>Echo<br>Venus<br>Mars | Goldstone |
| Woomera<br>Tidbinbilla<br>Booroomba[a] | Canberra |
| Johannesburg | |
| Robledo<br>Cebreros<br>Rio Cofio[a] | Madrid |
| Cape Kennedy (spacecraft monitoring) | |
| Ascension Island (spacecraft guidance and command) | |

[a] Station not yet authorized.

These stations are situated such that three may be selected approximately 120 deg apart in longitude in order that a spacecraft in or near the ecliptic plane is always within the field of view of at least one of the selected ground antennas. JPL operates the U.S. stations and the Ascension Island DSS. The overseas stations are normally staffed and operated by government agencies of the respective countries, with the assistance of U.S. support personnel.

The Cape Kennedy DSS supports spacecraft final checkout prior to launch, verifies compatibility between the DSN and the flight spacecraft, measures spacecraft frequencies during countdown, and provides telemetry reception from liftoff to local horizon. The other stations obtain angular position, velocity (doppler), and distance (range) data for the spacecraft and provide command control to (uplink) and data reception from (downlink) the spacecraft. Large antennas, low-noise phase-lock receiving systems, and high-power transmitters are utilized. The 85-ft-diameter antennas have gains of 53 db at 2300 MHz, with a system temperature of 55°K, making possible significant data rates at distances as far as the planet Mars. To improve the data rate and distance capability, a 210-ft-diameter antenna was built at the Mars DSS, and two additional antennas of this size are planned for installation at overseas stations. In their present configuration, all stations except the Johannesburg DSS are full S-band stations. The Johannesburg DSS now has a GSDS S-band receiver-exciter subsystem.

It is the policy of the DSN to continuously conduct research and development of new components and systems and to engineer them into the network to maintain a state-of-the-art capability. Therefore, the Goldstone DSCC is also used for extensive investigation of space tracking and telecommunications techniques, establishment of DSIF/spacecraft compatibility, and development of new DSIF hardware and software. New DSIF equipment is installed and tested at the Goldstone DSCC before being accepted for system-wide integration into the DSIF. After acceptance for general use, the equipment is classed as Goldstone Duplicate Standard in order to standardize the design and operation of identical items throughout the system.

## B. Ground Communication System

To enable communications between all elements of the DSN, the Ground Communication System (GCS) uses voice, teletype, and high-speed data circuits provided by the worldwide NASA Communications Network between each overseas deep space station, the Cape Kennedy DSS, and the Space Flight Operations Facility (SFOF, described below). The NASA Communications Network is a global network consisting of more than 100,000 route mi and 450,000 circuit mi interconnecting 89 stations, of which 34 are overseas in 18 foreign countries. Entirely operationally oriented, it is comprised of those circuits, terminals, and pieces of switching equipment interconnecting tracking and data acquisition stations with, for example, mission control, project control, and computing centers. Circuits used exclusively for administrative purposes are not included.

Voice, teletype, high-speed data, and video circuits between the SFOF and the Goldstone DSCC are provided by a DSN microwave link.

## C. Space Flight Operations Facility

During the support of a spacecraft, the entire DSN operation is controlled by the Space Flight Operations Facility (SFOF) at JPL. All spacecraft command, data processing, and data analysis can be accomplished within this facility. Operations control consoles, status and operations displays, computers, and data processing equipment are used for the analysis of spacecraft performance and space science experiments. Communications facilities are used to control space flight operations by generating trajectories and orbits and command and control data from tracking and telemetry data received from the DSIF in near-real time. The telemetry, tracking, command, and station performance data recorded by the DSIF are also reduced at the SFOF into engineering and scientific information for analysis and use by scientific experimenters and spacecraft engineers.

# V. DSIF Development and Operations

## THE DEEP SPACE NETWORK

## A. Flight Project Support

### 1. *Surveyor* Project

The Pioneer DSS continued *Surveyor III* spacecraft data transmission and data processing until the end of the first lunar day. Soil mechanics experiments and photographic experiments of soil sampling were performed through May 3. Eight separate attempts to revive the spacecraft at the beginning of the second lunar day were not successful.

The Pioneer DSS performed tests and practice operations in preparation for the *Surveyor D* launch, which was scheduled for July 1967.

### 2. *Mariner* Venus 67 Project

The *Mariner V* spacecraft was launched from Cape Kennedy, Florida, on June 14, 1967. Pioneer DSS provided primary tracking and command data transmissions during the first view period and midcourse maneuvers. Mars DSS performed backup tracking. A mutual view time correlation experiment between Canberra DSS, Pioneer DSS, and the spacecraft was performed.

### 3. *Lunar Orbiter* Project

The Echo DSS continued providing telemetry and command support operations for the *Lunar Orbiter II* and *III* spacecraft. The Mars DSS performed tracking for one pass, with the Echo DSS processing the data.

The *Lunar Orbiter IV* spacecraft was launched from Cape Kennedy, Florida, on May 4, 1967. The Echo DSS provided primary tracking and data command transmissions for all passes until completion of the photographic experiments on June 4. The photographic and scientific data transmitted by the spacecraft were processed by Echo DSS. A voice relay experiment via the spacecraft was conducted, and the results are being evaluated. Also performed were time correlation experiments with Madrid DSS. The spacecraft is on extended mission status and experiments continue.

## B. DSS Equipment Installation and Testing

### 1. Pioneer DSS

Multimission support recording equipment is being installed in the Pioneer DSS operations room. Cable installation and equipment testing are in process. The equipment consists primarily of telemetry and data recording equipment.

The 4-ft-diameter time-synchronization receiving antenna was installed in the station control building.

### 2. Venus DSS

Time synchronization, with a resolution of better than $\pm 5\ \mu s$, was accomplished between the Venus DSS (30-ft az-el antenna) and JPL, and between the Venus and Pioneer DSSs, using the moon as a reflector at an operating frequency of 8450.1 MHz. This resolution was made possible by the utilization of a newly developed ephemeris for the moon.

The 85-ft az-el antenna was utilized for telemetry reception from the *Pioneer VII* spacecraft at 2292 MHz, using rotatable linear polarization to maximize received signal strength. Using matched polarization and a $2B_{LO}$ bandwidth of 2 Hz in the phase-locked loop tracking filter enabled successful telemetry reception even though the antenna feed system, which is optimized for 2388 MHz, did not deliver maximum performance at 2292 MHz.

The performance of the 85-ft az-el antenna at 8448 MHz is currently being extensively investigated, using radio star tracking to investigate surface and structure deformation as a function of antenna attitude, and using the Tiefort Mountain collimation facility to measure gain and antenna patterns in the horizon look position. Preliminary measurements indicate a gain of 64 dB at 8448 MHz.

The planetary radar experiment, with Mars as the target, was concluded. Results were very good. The average round-trip range during this experiment was 640.7 light-seconds so the monostatic spectra represent approximately 11,618.5 min of data, while the bistatic spectra represent approximately 1,505.7 min of data. The 6-db gain superiority of the 210-ft antenna on reception is indicated by the quality of the bistatic data.

### 3. Mars DSS

The major portion of improvement work on the azimuth hydrostatic bearing was completed by May 1, and the Mars DSS resumed full-time operations. Tracking of the *Mariner IV* spacecraft was accomplished by utilizing R&D equipment. Ranging subsystem equipment for experiments relative to the *Mariner* Venus 67 project was installed and tested.

### 4. Johannesburg DSS

The Johannesburg DSS started operations in 1961 as an L-band system. The microwave and the receiver subsystems were subsequently modified (in 1963) to operate within the S-band frequency range; and in March 1967, the modified L-band receiver was replaced with a GSDS S-band receiver in the DSN block II configuration.

To implement the last modification, the following activities were performed:

(1) Cable trays were rebuilt to the new configuration and installed.

(2) Short interface adapter cables were fabricated to connect the standard system cables with the non-standard equipment.

(3) The suitcase telemetry receiver, the L-band transmitter, and the L/S-band receiver were removed.

(4) The analog instrumentation subsystem was rebuilt from an 8-cabinet to a 5-cabinet configuration that simulates the standard subsystem.

(5) The tracking data handling and frequency and timing subsystems, which are essentially one subsystem at this DSS, were modified to handle standard assignments.

(6) The new receiver, system junction module, and system cables were installed.

(7) The control room was laid out in the standard S-band configuration (Fig. 1).

On April 17, the modified Johannesburg DSS successfully participated in the *Surveyor III* mission as a fully operational station.

### 5. Cebreros DSS

Installation of the antenna mechanical subsystem at the Cebreros DSS was completed (Fig. 2). This is the third DSN 85-ft hour-angle/declination antenna installation of the new four-legged hi-performance configuration. The other installations of this type are at the Robledo DSS and the Tidbinbilla DSS.

The Cebreros DSS installation has improvements in the following areas:

(1) A new ladder configuration (wider, better shape) extends from the ground to the lower end of the hour-angle shaft.

(2) A modified walkway at the east side of the declination drive skid area provides improved safety and more area.

(3) Modified walkways over both declination bearings give improved safety and hour-angle travel.

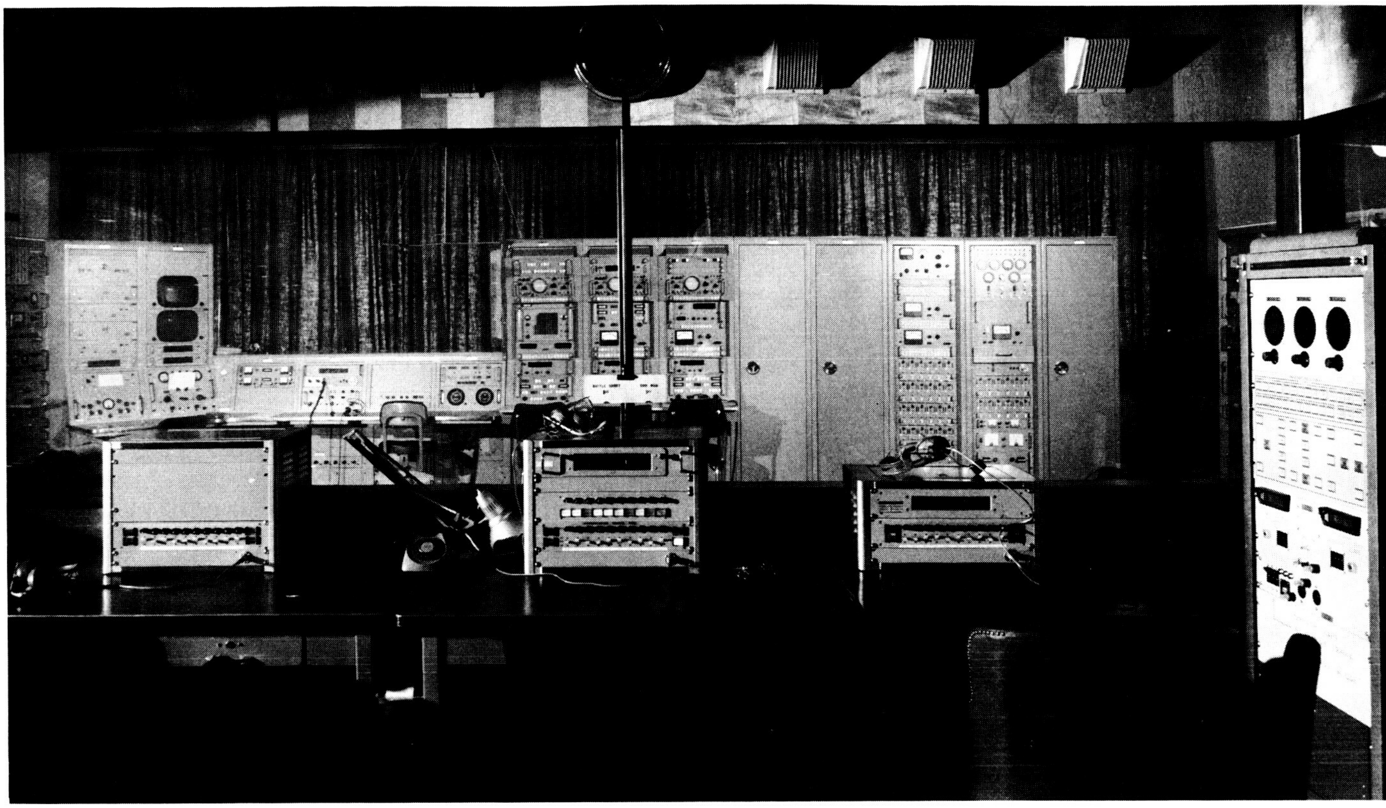

Fig. 1. Johannesburg DSS operations control room

Fig. 2. Cebreros DSS antenna mechanical subsystem

(4) New hour-angle and declination cable wrapups are provided.

(5) Additional double cable trays extend from the antenna support building to the antenna and into the upper electronics room.

(6) Improved structural connections are provided, including all face panel attach bolts. These connections were made using the new "turn-of-the-nut" bolt tightening procedures, which give more uniform tensioning to all bolts.

(7) New light towers are provided for night work and emergency repairs.

### 6. MSFN Modifications (Pioneer, Tidbinbilla, and Robledo DSSs)

The Pioneer, Tidbinbilla, and Robledo DSSs were modified so that they can provide operational support to the Manned Space Flight Network (MSFN) project *Apollo*, as well as fulfill all DSN tracking commitments. The following modifications to configurations were made:

(1) Antenna structure: new cable trays, hour angle/declination wrapups to handle DSN/MSFN cable run installation, service platforms, and safety rails.

(2) Upper electronics room: new maser, MSFN receiver racks, and MSFN 20-kW power amplifier.

The optical tracking aid and the collimation tower assembly were modified to accept DSN/MSFN interface. Preliminary controls in the operation centers of the DSN and MSFN wings were paralleled with transfer switching to implement specific control to the wing in configuration control, and by installing required optical boresight targets on the collimation tower.

## C. Communications Development and Testing

### 1. Multiple Mission Telemetry System

The Jet Propulsion Laboratory has been recovering telemetry from space vehicles for ten years. Over this period, wide ranges of subcarrier frequencies, data rates, and types of modulation have been used. Each project has selected parameters for its telemetry requirements, and, because each was different, the ground demodulation equipment has differed. This has necessitated equipping ground stations assigned to a particular mission with "mission-dependent" demodulation equipment which has varied from 5 to 20 racks per station. While providing maximum design freedom, this system was costly in equipment, installation time, and training time. It also limited DSN flexibility, since only stations having the mission-dependent equipment could support that mission.

The *Mariner IV, Pioneer, Lunar Orbiter, Apollo, Mariner* Venus 67, *Mariner* Mars 1969, and *Voyager* spacecraft use, or will use, PCM-PM-PM[1] as the telemetry mode. Therefore, this mode is evolving into a standard for deep space communications. This project recognizes this mode of telemetry transmission as a standard and provides general-purpose mission-independent equipment capable of meeting all mission requirements at each DSN station. The universal nature of this equipment makes it a long-term installation to handle engineering and medium rate science telemetry.

The multiple mission telemetry system consists of a subcarrier demodulation loop which accepts 10-MHz signals from the receiver, phase-modulated with one or more square wave subcarriers which, in turn, are phase-modulated with data. The demodulation is accomplished in a manner which does not lose the power in the square wave harmonics. Bit synchronization is accomplished in a computer operating in conjunction with special-purpose digital equipment by using the transitions in the telemetry data stream. To change from one spacecraft to another, it is only necessary to change the computer program and reset the subcarrier voltage-controlled oscillator, certain bandwidths, and time constants. Ultimately, this will all be accomplished from the computer program.

A separate channel for subcarrier and bit synchronization is not required from the spacecraft; therefore, this power may be used to increase the power in the information channels. A fixed-phase relationship between subcarrier and bit timing is no longer required. This removes the requirement for rigid bit timing in the various spacecraft data sources and results in simplification of the spacecraft subsystem interfaces. This simplification of spacecraft electronics is expected to increase reliability.

The multiple mission telemetry system also includes dual back-up data recordings for recovery of data in the event of equipment malfunction. Each multiple mission telemetry system can handle one subcarrier. Two systems will be installed at each station, but dual channel operation will be possible only if two computers are available. The entire system will consist of two racks installed with the receiver/exciter subsystem housing two subcarrier demodulators and two racks installed with the telemetry and command processor housing digital equipment. The existing SDS 920 computers will be used. One additional rack of signal simulation or test equipment will be provided at each station.

### 2. DSIF Monitor Program (Phase I)

The DSIF monitor program (phase I) is the software counterpart of the digital instrumentation subsystem (phase II) hardware development. The digital instrumentation subsystem, together with the monitor program, dictates the operating modes of the DSIF monitoring subsystem (phase I) in the performance of the station monitoring function. The monitor program controls the station instrumentation and system monitoring tasks within each station in the DSIF. The program directs the functions of: (1) station configuration, performance, and status monitoring; (2) alarm monitoring of selected critical parameters; (3) preparation of a permanent record of station performance and failure data in magnetic

[1]Pulse code modulated–phase modulated–phase modulated.

tape and tabular form; and (4) communication of alarm messages and periodic reports to the DSIF and the DSN.

The monitor program performs the three primary functions of data input and collection, data processing, and data output.

The data input function involves the collection and storage of: (1) station monitor parameters, (2) monitor criterion data (predicts), (3) inter-range vector parameters, (4) calibration data, (5) initialization inputs, (6) control criteria, and (7) recovery elements (error detection and correction techniques).

The station data gathering function requires the sampling of all system and subsystem parameters at the rates established within the program. Input parameters provided to the digital instrumentation subsystem consist of analog and digital data, station time, control signals, and calibration data. Data presented in analog form is converted to digital form for storage and processing, together with the digital input data. The program monitors the following station functions: (1) DSIF system configuration, (2) DSIF subsystem status, (3) signal strength, (4) doppler, (5) angle, (6) range, and (7) transmitter and receiver parameters, and provides the capability for future expansion to include (8) mission-dependent equipment and (9) facilities monitoring.

The data processing function consists principally of: (1) comparison of actual performance against preestablished standards for recognition of nonstandard operating conditions; (2) computation of residuals, means, and standard deviations for input parameters; (3) blunder point determination and rejection from calculations; (4) scaling, editing, linearizing, differencing, normalizing, and conversion of data to engineering units; (5) application of stored calibration characteristic curves to input data; (6) interpolation, extrapolation, and fitting curves to discrete point data; (7) predict computation of spacecraft position message inputs; (8) alarm detection and generation, using correlation and limit checking; and (9) message format structuring and recognition.

The output function is composed of alarm messages (at time of occurrence), periodic reports (at 5-min intervals), summary reports (once per pass), and permanent station performance and failure data in magnetic tape and tabular form. The alarm messages are concise descriptions of the failed function and are displayed locally at the DSIF station via a page printer and line printer. The alarm message is also transmitted to the SFOF by way of a teletype communication channel. Actuation of the appropriate sense switch on the station control and monitor console will provide a high-resolution printout of the failed function, at the full sample rate, together with suitably annotated messages.

### 3. SFOF Data Processing System

The on-line computing capability in the Space Flight Operations Facility (SFOF) comprises three computer strings (W, X, and Y). Each string consists of an IBM 7044 computer with a drum, an IBM 7094II computer and a shared disk. Each string is provided with a direct data connection code, between the 7044 and 7094, which is used for direct intercomputer communications. The 7044 is provided with an IBM 7288 data communications channel through which all data input/output and user input/output devices are handled.

Three IBM 7040s and one SC 4020 are used for generation of off-line prints and plots. Each off-line computer uses as an input source data tapes generated by on-line computers, such as the 7044 and the 7094.

There are four sources of data input, other than from user devices, into the SFOF data processing system (Fig. 3): (1) the telemetry processing system, (2) the communications processor, (3) the timing system, and (4) the simulation data conversion system.

The telemetry processing system does all preliminary processing of telemetry data, other than that received by TTY, before passing the data to the 7044 input/output processor. The communications processor system does all routing of incoming and outgoing TTY information in response to routing information contained in each message header.

Two groups of equipment are available for timing. The first is on-line with the SFOF computers and provides the GMT reference for the SFOF. The capability exists to synchronize the on-line generators to time signals received from Goldstone, the JPL Standards Laboratory, and the National Bureau of Standards radio signals from WWV and WWVB. The second group is off-line and provides facility time displays during simulations and missions.

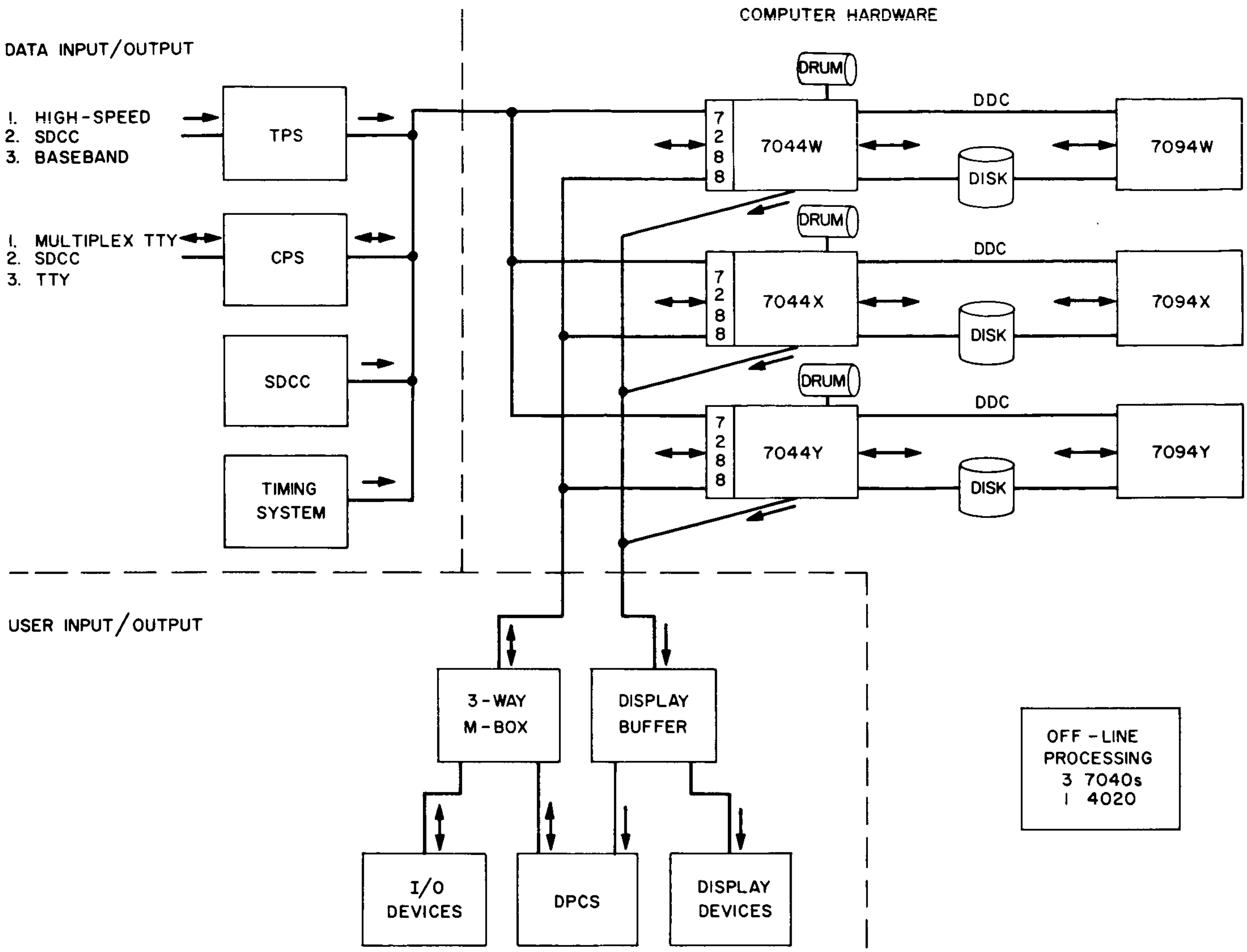


**Fig. 3. SFOF data processing system**

The simulation data conversion center provides simulated data directly or via the deep space stations into the SFOF for systems checkout and for training of mission operations teams. It provides simulated data inputs to the telemetry processing system, the communications processor, the 7044s, and to the deep space stations via real-time interfaces and analog magnetic tapes. Data is generated in serial digital, parallel digital, modulated subcarrier, or teletype forms.

All user input/output devices in the SFOF, with the exception of the data display teleprinters, are interfaced with the 7288 subchannels through the three-way M-box. The position of a given M-box switch determines with which string (W, X, or Y) a given input/output device will communicate. The position of each such M-box switch can be determined locally at the M-box, or remotely at the data processing control and status consoles.

The display buffer accepts mission-independent inputs from the SFOF's 7044 computers. These data are manipulated as necessary and output to mission-independent hardware. At present, two hardware displays of this type exist. One is the flight-path analysis area No. 2 orbital parameters display and the second is the data processing control and status console. Total capabilities in these areas will not be available until 7044 coding is completed and checked out.

The means for monitoring and controlling the SFOF data processing system lies in the data processing control area. The physical hardware comprises a standard input/output station and an equipment group known as the data processing control and status system, which has three consoles: (1) the equipment status display, (2) the processing status display, and (3) the data status display. These displays furnish comprehensive and timely indication of the operational status of various systems and equipments throughout the SFOF and also provide control over the assignment of input/output devices to the W, X, and Y computer strings as dictated by operational requirements.

#### 4. Digital Tracking System

Recent developments at JPL have led to the concept, feasibility studies, and in some cases, prototype construction and testing of several new subsystems which fall into the general classification of digital spacecraft tracking equipment. These subsystems are:

(1) Tracking data handling subsystem (phase II), which will replace the phase I subsystem; it will offer considerably greater functional flexibility and greater operational reliability.

(2) Ranging subsystem (phase II), which will replace the phase I subsystem at the Mars DSS and will be the only ranging subsystem to be installed at the two additionally planned 210-ft-diameter antenna stations (Booroomba and Rio Cofio DSSs); it will permit range determination to planetary distances as opposed to the lunar-distance limitations of the phase I subsystem.

(3) Programmed local oscillator subsystem, which will tune the local oscillator of each of the two S-band receivers at a station in accordance with frequency requirements periodically determined by the computer.

(4) Programmed exciter subsystem, which will tune the transmitter exciter at a station in the same manner as the receiver oscillators will be tuned by the programmed local oscillator.

Inasmuch as each of the above subsystems would include a general-purpose digital computer, it was decided to consolidate the design of all the subsystems to incorporate but a single computer. The resulting digital tracking system will include a tracking data handling subsystem (phase II), a ranging subsystem (phase II), two programmed local oscillator subsystems, a programmed exciter subsystem, and at a later stage of development, an antenna pointing subsystem (phase IA).

Initially, the digital tracking system will have a tracking data handling subsystem (phase II) and a ranging subsystem (phase II) configuration. The design of the tracking data handling subsystem (phase II) will include the following improvements:

(1) Greater versatility in data acquisition with sampling rates up to 1000/s on some types of input data.

(2) Versatile data format control and message header flexibility with optional data editing.

(3) Data conversion and application of station calibration information.

(4) Addition of a doppler resolver and simplification of doppler mode selection.

The design of the ranging subsystem (phase II) will be based on developmental ranging equipment presently installed at the Mars DSS for evaluation during the *Mariner* Venus 67 mission. The following improvements over the phase I ranging subsystem are expected:

(1) The system design will permit range determination to planetary distances with spacecraft transponders identical to the turnaround type presently used on *Mariner* spacecraft. Calculations have been made which indicate adequate ranging sideband power is available at the Venus or Mars DSSs with the use of a 210-ft-diameter ground antenna.

(2) The acquisition time will be about 1/6 of that required for the phase I ranging subsystem for the same signal strength. The number of code correlation measurements will be 1/3 of that used now, due to a shortened code length; furthermore, the ranging receiver will have two channels operating simultaneously, which will reduce the acquisition time by another factor of 2.

(3) Subsystem reliability and greater insensitivity to environmental conditions will be ensured by the use of the recently developed Hi-Rel digital modules.

#### 5. Antenna Pointing Subsystem

The antenna pointing subsystem computer program, which computes an ephemeris from injection conditions at launch, has been completed. This operation mode, known as the injection condition mode, enables the antenna to be pointed at the spacecraft by computing the spacecraft ephemeris from seven injection parameters. These parameters, which are sent to the station via teletype or voice line, are fed into the antenna pointing subsystem computer by either paper tape or typewriter input. If the spacecraft is still below the horizon after ephemeris computation, the antenna will be pointed toward the predicted rise point at the horizon. At spacecraft rise-time, the antenna will be updated to the computed spacecraft ephemeris.

This program has been tested and compared with results obtained from an operational program JPTRAJ-SFPRO which was run on the IBM 7094 computer. The results were extremely satisfactory. Errors between the two programs were in the order of 0.001 to 0.009 deg. The 0.009-deg error was obtained after a 24-h run and would normally not be encountered since injection condition parameters are periodically updated.

### 6. Optical Tracking Aid Assembly

An optical tracking aid assembly was installed on the 18-ft polar mount antenna at the JPL Table Mountain radio telescope installation near Wrightwood, California (Fig. 4).

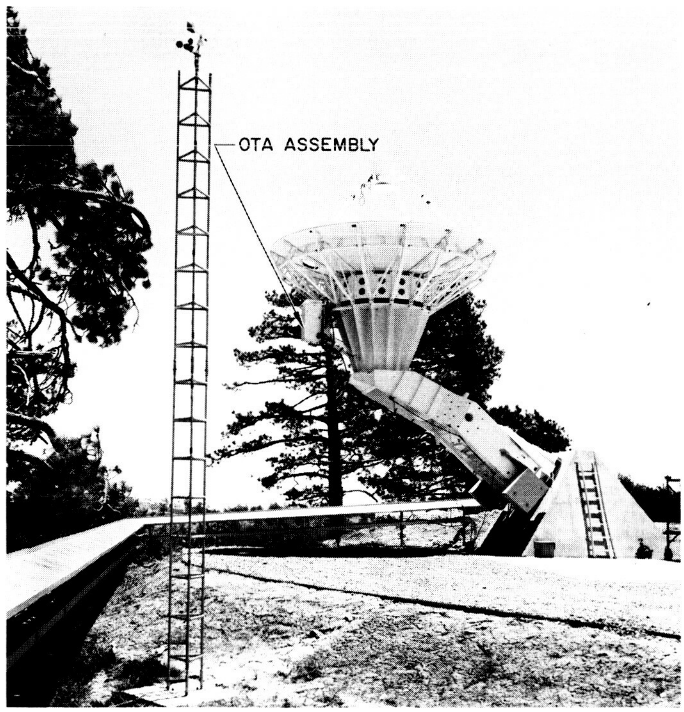


**Fig. 4. Optical tracking aid assembly on 18-ft antenna at Table Mountain radio telescope installation**

The optical tracking aid assembly provides optical support for the 18-ft-diameter radio telescope antenna in the areas of (1) star tracking calibration of the apparent geometric axis and tracking axes, (2) angle encoder boresight checks, (3) RF boresight checks, (4) optical acquisition and tracking of celestial bodies, (5) RF snap-on tests, (6) radio star optical tracking, where possible, (7) RF horizon mask determination, (8) star track evaluation of angle encoding equipment, (9) RF equipment gain and pattern measurements, and (10) planetary radar optical tracking.

The optical tracking aid assembly is designed around a cassegrain, reflecting type, $f/8$, 40-in. Zoomar telescope for maximum light gathering capability. A closed-circuit TV system is used to present the telescope image conveniently to the antenna operator at the control console. An illuminated reticle image, introduced onto the optical axis of the telescope, is registered by the TV monitor and provides a visual reference of the centerline of the antenna geometric axis. Controls for reticle illumination intensity and selection of neutral density filters are provided to compensate for varying light conditions and contrast. The antenna-mounted assembly is housed in a weatherproof, rugged weldment for maximum stability with minimum weight. A motor-actuated, slide-mounted cover assembly permits unobstructed viewing through the telescope while protecting the sensitive telescope and TV camera from rain, snow, or wind-blown dust. A manually-viewed $\times 32$ telescope facilitates precise collimation of the Zoomar telescope axis with the antenna reflector geometric axis and provides an auxiliary reference for boresight operations. Both telescopes are mounted as an optical components subassembly which can be adjusted to precise alignment independently of the exterior housing.